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EDITORIAL

THOUGHTS ON AUTUMN PAST AND PRESENT

THERE are some who welcome the turn of the year when the long dark evenings come and the trees paint in glorious colours before they spread their leafy winter carpet on the ground. Autumn glory lasts only for a transient period, it is superb, and often nature in her beneficience makes it a time of Indian Summer. Those who are growing old and have to wend their way in the open air can be excused if they do not share wholly in the rapture that misty autumn brings to those who are young or of artistic bent. It may be that their soul has lost some of its mellow æsthetic blend or perhaps it is because they know that the beauty is only temporary, it is wistfully elusive, and is the foreboding of dire winter which inevitably must come. It is a stout heart that can welcome the coming of snow, ice and fog and in this manner there must be few veterinary surgeons, and especially those who practise in country areas, who are so vigorously robust in this organ that they can anticipate with pleasure the dark days ahead.

In times gone by, before the advent of the automobile, life in the winter time was exacting. Long journeys in an open trap or gig, frozen ears, hands and feet and a melton coat so wet and rigid that one could stand it upright against the wall. Miserable lights from candle or paraffin lamp to illuminate the accouchement chamber and the thought of undressing in a cold and clammy barn, under primitive hygienic conditions, was a form of excruciating and exasperating mental and physicial torture. Veterinary surgeons had to be tough. It is no wonder that their insurance risk was rated at a high level and that when principals sought the service of an assistant, good physique had precedence over academic attainment. By comparison, life is easy in present times. It is not necessary to possess the frame of a

Hercules in order to be a competent and successful veterinary surgeon and calls on a winter's night are shorn of most of their terrors. With a turn of a switch a comfortable enclosed and heated vehicle springs to life and the way is flooded with light. At the farm, the veterinary surgeon can step lightly and cleanly from a cosy car to a warm, well lighted hygienic byre or stable where there are ample supplies of hot water, soap and towels. Gone are the days of a bucket of cold water, a piece of sack and a handful of soft soap.

After the job is finished he can return home in a few minutes in the greatest of comfort to a centrally heated house, with a pot of hot coffee simmering on the ever-lighted slow combustion stove and probably the blessing of an electrically heated blanket when he regains his bed. Only those of mature years have a true idea of the great changes that have come to pass in a veterinary surgeon's way of life during the last twenty-five years.

The automobile has been a principal factor in this revolutionary process. It is an instrument which our forebears looked upon with misgiving and some disgust. They deemed that it would portend to deprive them of their living. It has restricted and in some cases closed one lucrative sphere of endeavour but, in compensation by its mobility and comfort, it has opened up many more and now veterinary service is in greater demand than at any time in the history of the profession.

All the dire prognostications of our fathers have proved to be invalid and the erstwhile ogre has become a beneficient friend.

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GENERAL ARTICLES

HIGHER NERVOUS ACTIVITY IN DOMESTIC CATTLE

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Introduction

In previous papers (Brownlee, 1939, 1950, 1954) I described what I now classify as forms of " lower " nervous activity in cattle. Before the main subject of " higher " nervous activity is proceeded with in this present communication, these lower forms (Types (i) and (ii)) will be recapitulated in order to illustrate the differences between them and the " higher " forms and to show the relationship of " lower " to " higher ". The forms of " higher " nervous activity dealt with are (A) Learning, (B) Memory, (C) Appreciation of Spatial Relationships, and (D) Use of Previous Experience in New Situations.

Lower Nervous Activity

Type (i). Behaviour shown in response to stimuli arising from within the animal organism:—

(a) *Rumination reflex* and subsequent remastication of food.

(b) *Urination posture.* This posture is adopted on the very first post-natal occasion of urinating (3½ hours after birth on an actual observation). I have stated that no postural change occurred in the male ox on micturition (Brownlee, 1950); this is an error as slight elevation of the tail-head does occur in the male and this elevation is more marked in at least some new-born bull calves than it is in older animals.

(c) *Defæcation posture.* This is adopted by the calf on the first post-natal occasion of defæcating (1½ hours after birth on an actual observation).

(d) *Stretch-behaviour pattern.* This is seen in the calf on the first post-natal occasion of rising up after an extended resting period (2 hours 20 minutes after birth on an actual observation). The stimuli mediating this behaviour probably arise from muscle and joint proprioceptors.

(e) *Skin-licking.* Within 24 hours of their birth calves have been seen to lick their own skin. It might be objected that this is a response to stimuli from without the animal organism, as indeed it is in the case, for example, of calves infested with lice when the irritating stimulus is from a source strictly outwith the host's body, but this stimulus is nevertheless in immediate contact with the sensory mechanism of the host and no appetitive behaviour is required in order to experience the sensation. Healthy cattle free from visible parasites or other irritants groom themselves regularly.

(f) *Shaking-behaviour pattern.* The circumstances governing the occurrence of this behaviour are not clear. Presumably it serves to dislodge dust and debris from a large area of skin. It has been observed to occur in a calf within 24 hours of birth when it was carried out efficiently.

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These above are all innate behavioural responses to stimuli arising from within the animal organism, all capable of being performed perfectly or at least adequately on the first post-natal occasion of the operation of the appropriate stimulus and in connection with all of which higher nervous activity does not normally occur. It may be noted here that on one occasion a cow was observed so to orientate her body, whilst urinating, that urine, which, at the commencement of micturition was being blown by a strong wind on to the hind limbs, thereafter fell clear to the ground. Geldings may learn to avoid splashing of urine on to the skin by waiting to micturate till the groom places straw on the bare floor under them. The case of bulls and bullocks on the other hand differs in that (i) bedding is usually present; (ii) micturition is performed much more slowly than in the male horse; and (iii) the prepuce is nearer to the ground level and for these reasons the need which would favour learning of this kind does not arise. Moreover, it will be clear that the stimulus-response reaction, i.e., avoidance of splashing of urine on to the skin, with which this learning-to-avoid is associated, arises not from within but from without the body and thus strictly should have been dealt with under heading A(e) Self-Preservation below.

Type (ii). Innate behaviour elicited by the animal's instincts—drive, appetitive behaviour and goal: As in the case of the behaviour patterns listed under Type (i), the instinctive drive, the appetitive behaviour and the goal components of the instincts are innate and unlearned. The difference lies in that, whereas in Type (i) behaviour there is already immediate contact within the body between the exciting stimulus and the sensory organs which connect with the operating motor mechanism and thus no appetitive behaviour is required to effect such contact, in the case of Type (ii) behaviour the relevant stimuli come from elements in the environment and appetitive behaviour is necessary to bring them within reach of the sensory organs, e.g., food must be sought for in the environment before contact of the food with the mouth can be established and the food swallowed.

It is in connection with this appetitive behaviour that the higher nervous activities of learning and memory are so valuable in that they enable the animal to economize on the amount of appetitive behaviour requiring to be expended, for example, when by the appetitive behaviour of the hunger instinct a source of food has been found, the ability to learn and memorize enables the animal to return to this source of food without researching, or when by the appetitive behaviour of the curiosity instinct a strange object has once been examined then the memory faculty renders unnecessary any reinvestigation of the same object.

Higher Nervous Activity

Higher nervous activity consists of the modifications in behaviour resulting from the animal's ability:—

(i) to experience, and record in the memory, sensations resulting from the contact of sense organs with stimuli from the environment, the animal itself being passive, e.g., being groomed—a pleasant sensation, or being butted or being exposed to cold and wet winds—unpleasant sensations. That such a record is actually made is indicated solely by the fact that the animal

on subsequent similar occasions will generally act so that the pleasant will again be experienced and the unpleasant avoided;

(ii) to carry out motor actions and to record the sensations resulting therefrom through contact of sense organs with stimuli in the environment, e.g., to gallop-play on a bare cement floor or to touch an electrified wire or to taste or smell noxious plants—unpleasant sensations, or to gallop-play on a bedded floor or rub skin against a suitable fixed object—pleasant sensations, and so to act on future occasions that the pleasant will again be experienced and the unpleasant avoided;

(iii) to record the effects of its own actions on the environment, e.g. (*a*) a cow roaring may induce its calf or another congener within hearing to respond by roaring, or (*b*) pushing head between the wires of a fence may cause the wires to give and as a result the head can be pushed through, or (c) pushing the muzzle against the valve-elevator of the water-bowl will cause water to flow, and to repeat such actions on future occasions when it would be of benefit to do so;

(iv) to become habituated to stimuli, at first appearing harmful but with experience found to be harmless, such as trains passing the pasture field, or being tied up, or the various movements of attendants with their equipment used in cleaning, bedding, feeding, milking, etc.;

(v) to profit from the results of the actions or sensations of past situations when confronted with similar situations or even with new ones which contain elements of several already experienced.

An account of the various types of learning is given by Thorpe (1951).

The reader will find some confusion in the section below, headed "(C) Appreciation of Spatial Relationships". The reason for this is that further observations would be required to distinguish completely what behaviour is innate and what results from learning.

Collection of Data

No *ad hoc* experimental work has been carried out. The observations on which this paper is based have been made over a period of years, and usually the behaviour described has been elicited under quite undesigned and uncontrolled circumstances.

(A) Learning

The following are examples of learning observed in relation to the following instincts: (a) maternal and filial; (b) food collection; (c) play; (d) curiosity; (e) self preservation; (f) social grooming.

(a) *Maternal and filial instincts:* At the time of parturition the cow has a marked unlearned appetite for the uterine fluids and for the placenta (Brownlee, 1950), and she licks the calf clean all over with great avidity. This licking is probably a means of forming a bond between mother and offspring facilitated by the maternal instinct of the dam and the filial instinct of the calf as the close contact during licking enables cow and calf to see and smell each other and thus

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the cow learns to know its own offspring and the calf begins to learn to know its own mother, and by the time this licking is completed it may be difficult thereafter to get the cow to take any other calf. It appears that the cow learns to know the offspring before the offspring the cow. The calf probably also experiences a feeling of comfort while being licked in contrast to the slimy and cold wetness of the unlicked state, and this probably aids in attracting the calf to the cow. In addition, while licking and afterwards, the newly-calved cow, at frequent intervals, utters a soft low and when she wishes to attract the calf this low is repeated. Should the calf become separated from the dam, to attract the calf she will roar loudly and the calf, if within hearing, will reply.

(b) *Food collecting instinct:*

(i) When the new-born calf is hungry it makes for its dam and having reached her it begins to thrust its muzzle against the parts of the under surfaces of the dam's body and suck the skin, especially prominences on the skin. The calf thus may thrust and suck at the dewlap, brisket, axilla, sternal region, etc., or at the udder, doing so in any order according to what appears to be chance but always with a tendency to contact under surfaces. This thigmotropic activity enables the calf eventually to reach a teat, a prominence the shape of which facilitates sucking and, on sucking, it is rewarded. The cow quite often turns round to lick the calf or may lift a hind foot gently to ward off the calf. Then the calf has to begin again in search of a teat but it succeeds more quickly than on the first occasion and, within a matter of hours of being born, the calf has little difficulty in finding the teats and soon dispenses with all search elsewhere, making directly for the udder when hungry. All calves have this ability to learn the elements of that situation in which milk is obtainable and to replace thigmotropic behaviour by learned behaviour. However, should the calf be removed from its dam and thus from its known source of milk it will resume thigmotropic behaviour in a new search as is well exemplified in the calf's thigmotropic searching of the person of its attendant.

(ii) Calves can be taught to drink milk from a bucket by giving the calf one's finger to suck and then guiding the muzzle into the milk in a bucket and repeating this until the calf has learned to drink without sucking fingers. They also learn to drink milk from the bucket without the presence of the attendant. Thus the calf has learned the elements of the new situation in which milk is to be found. They learn to come for food on hearing their attendant's call and, when at pasture, to know their way to the pasture field and the site of the water supply. Cattle that are fed and attended to regularly each day soon learn to associate their time of being fed with the sounds and movements made by the attendants.

(iii) It is well recognised that cattle are not tool-using animals. Under certain circumstances their ability to extend the neck and tongue may enable them to reach food; also they will place the fore-feet on a suitable raised platform to enable them to reach a high object and get down on their knees to reach food placed low under an obstructing object such as a wire fence.

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(iv) A bull, housed in a loose-box and being fed on mangolds placed in a long trough with glazed inner surface, learned to throw the mangolds out of the trough using the side of its muzzle for this purpose (photograph 1). It then proceeded to eat the mangolds on the bedded floor (photograph 2) where prehension was easier than in the glazed trough where the mangolds tended to slip ahead on each attempt at biting, a difficulty overcome by most animals by wedging the mangolds against the end of the trough. The bull probably threw the mangolds out on to the floor accidentally to begin with and then, realising the benefit, continued to do so purposely. This would appear to be an example of the animal's ability to observe the effect of its own actions.

(c) *Play:* An account of play in domestic cattle has been published (Brownlee, 1954) and here my subject is play in relation to learning.

(i) Cattle, even calves only a few weeks old, being kept in a cement-floored yard or loose-box only part of which is bedded, soon learn to play entirely or almost entirely on the bedded portion; presumably the hard and often slippery bare cement causes the animal to receive unpleasant sensations which lead it to seek the bedded part and avoid the unbedded.

(ii) Sexually immature cattle during play will attempt to mount other such cattle which immediately turn about sharply or else try to dislodge the mounter by running off. It would appear that the mounter takes notice of its own action in bringing about this avoiding action on the part of mounted animals and, if a number of cattle sufficient to occupy all the available space at a hay rack are feeding and it wishes to get access, it may mount one of those already feeding which turns about and so leaves room.

(iii) The strong urge to head play with various movable objects, animate and inanimate, is a feature of cattle play. They appear able to take notice of the results of their play. Thus one heifer, presumably playing with its water bucket and by chance dropping it over the closed half-door of its loose-box, was able purposely to repeat this feat on a number of occasions, though it was never actually observed to do so. Another heifer could open its loose-box door by pushing across the bolt with its muzzle and then pushing open the door (photographs 3 and 4). Having thus escaped into the exercise yard it could then proceed to use this ability in a similar situation and open other doors from the outside. Yet another heifer could open its loose-box door by pushing across the bolt with its horn and another could turn on the water tap at will and commence to drink, or toy with, the running water. It is noteworthy that all these animals had been kept in the same or similar environment for most of their lives so they had extended opportunity to learn relationships within that environment; even so, only an occasional animal out of about twenty heifers similarly housed for extended periods learned to perform any one of these actions and, also, it was not until they were about or over two years old that these learned activities were observed so that long familiarity with the relevant objects would appear necessary for such learning. However, without having observed the exact circumstances under which these animals learned to perform these actions, one cannot be certain about how often they had to encounter the relevant components of the situation before perceiving

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relationships. The requirement of previous familiarity would conform with the findings of Birch (1945) who observed that chimpanzees required to be familiar with the general handling of sticks before they could use them for retrieving food otherwise out of reach.

(d) *Curiosity:*

(i) Within an hour or so of being born an active calf may be seen walking round its loose-box apparently examining the various objects in its environment, thus, by this appetitive behaviour, putting itself in a situation where stimuli will reach the sensory nerve-endings responsible for mediating sight, smell, touch, hearing and taste. That the nature of the sensations thereby experienced is recorded in the memory is indicated by the fact that if any new object is introduced into an already familiar environment, it is immediately recognised as new and is investigated with the senses at the alert. No notice appears to be taken if a known object (e.g. wheel-barrow) is moved from one part of the environment to another.

(ii) A heifer, which was being kept in a confined environment, immediately recognised as a strange object a wheel-barrow wheel, which had been detached, cleaned, repaired and then returned to await reattachment.

(iii) A heifer was transferred from one loose-box to an adjoining box of similar construction except that in the new box the feeding trough was divided into two by a brick and mortar division. The heifer immediately observed this division and went to investigate it with senses at the alert. The remainder of the box it appeared to accept as being already familiar.

(iv) Young calves, which have been kept continuously for an extended period in one loose-box, when given the opportunity to go out will sniff and stare at the new terrain and only after much hesitation will they venture forth from their familiar surroundings.

(e) *Self-preservation:* To preserve the body as a whole from attack the organs of defence and offence are the head and horns and the hind feet, and in a situation where these are inadequate, flight is resorted to. Self-preservation also comprises the avoidance of contact of parts of the body with obstacles or other harmful agents. That learning and memory are associated with self-preservation is shown by the following examples:—

(i) The cattle concerned were a group composed of pairs, each pair having been reared together in their own separate loose-box. These animals were all put to one pasture and in order to make clinical records they were taken back to their loose-boxes, but for convenience it was desired to put three animals in one loose-box—one pair and an odd one. The odd animal when in the loose-box was butted by the pair. Next day, when an attempt was made to repeat this same grouping, the odd animal took evasive action to avoid being boxed up a second time with the pair.

(ii) During a period of frost the cement-floored exercise yard, adjoining the loose-boxes, became wet and then frozen. One animal had great difficulty in maintaining foot-hold when allowed out from its box. Next morning when given opportunity to go out she remained within, whereas normally all

the animals very willingly went out into the exercise yard. Incidentally this animal, a very docile one, showed head-shaking behaviour (see Brownlee, 1950, for the conditions of occurrence of this behaviour pattern), and it would appear probable that this was a displacement reaction induced by a conflict between desire to go out of the loose-box and fear to do so.

(iii) Cattle on first being tied up in their stall struggle to get free until the novel situation is accepted. Having learned to accept they can now be chained in the same or in a new stall without further struggling and under certain conditions they will stand at the pasture-field gate awaiting opportunity to get back to their stalls again, presumably having learned that there food, etc., becomes available to them. A careful cattleman may be able to walk about among his charges without their showing any fear of him. These are examples of habituation. On the other hand, a young bull being led daily along the same route always became excited and frightened when it arrived at one particular point. The offending object was not determined. Another similar animal being led along the same route at the same times took no notice.

(iv) See below under "Appreciation of spatial relationships (ii)".

(f) *Social Grooming:* Cattle show a definite drive to lick other cattle. I have seen calves only a few weeks old licking other calves and a calf reaching over its individual calf-pen partition in order to lick its neighbour. In a herd, cattle appear to realize the value of this drive to their individual benefit and one animal may be seen to approach another and stand still apparently expecting to be licked and, if the wrong area be licked, the recipient may so orientate its body as to bring the itchy part within easy reach of the licker's tongue. A person can in the same way act as groom. On several occasions I had stroked the neck of a cow and she learned to approach me in the same manner as she would a member of the herd and stand still expecting me to groom her (photographs 5 and 6).

(B) Memory

The two examples given above under headings A(e)(i) and A(e)(ii) illustrate powers of memory in cattle. Other examples are:—

(i) A herd of cows, at pasture by day and housed by night, were changed one afternoon from a relatively bare pasture to an abundant one. Next morning many of the cows proceeded in the direction of the abundant pasture instead of to their customary bare one.

(ii) Cattle can return to their own stall after being continuously at pasture for several months (see Brownlee, 1950).

(iii) A bullock had been milk fed as a calf from bottle and teat. When this equipment was presented to this animal when it was approaching two years of age it began to suck the teat as formerly.

(C) Appreciation of Spatial Relationships

(i) A herd of dairy cows at Compton was being strip-grazed, an electric fence being used. (See photograph 7. The photograph was not taken at the actual time of the incident.) At the time of the incident most of the cows

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were grazing in the vicinity of the point X. A group of cattle transported by road was unloaded from a motor-truck at a gateway into another field near the point A. The cows at X saw the unloading and were interested, as indicated by their looking towards the scene and alerting their ears, but they did not move one step in that direction apparently realizing that, had they approached the short distance to the electric fence barrier, there would still be a great distance (some 500 yards) between them and the unloaded cattle. When, however, the unloaded cattle commenced to gallop in the direction A —▷ B, many of the cows galloped wildly from point X towards point Y and the two herds, when at the terminus of their respective gallop, were only the distance of the roadway apart. That the cows did not move towards the stranger cattle on first seeing them probably resulted from an innate ability to appreciate spatial relationships of this kind as I do not recall having seen young calves to behave in a manner such as would indicate inability to do so. (See also below under heading "(D) Use of Previous Learning in New Situations").

(ii) A few cows, one with new-born calf, were confined in a long, rather narrow, rectangular yard. A Friesian cow which was afraid of the cow with the calf was close to one end of the yard and when the cow with the calf approached towards her she took evasive action by quickly by-passing her enemy and so gaining the open yard. The same proceedings occurred at the other end of the yard, the Friesian cow apparently realising the danger of being confined in a comparatively narrow space whilst an enemy was approaching.

(iii) A heifer has been observed to lower its back when passing under the top half of a hinged door which was in the partly open position. This is probably an innate avoiding reaction as I do not recall any evidence that young calves require to learn to avoid obstacles of this kind.

(iv) Some cattle, when confined to strip-grazing by an electric fence, learn to get down on their knees and to push the head under the fence in order to graze as far as they dare, apparently having the ability to appreciate the spatial distance between their necks and the wire.

(v) Some cattle are very unwilling to lie down on dirty bedding and one in particular was observed to lie down close into a corner of the loose-box where the bedding was cleanest, apparently being able to judge quite accurately its body's space requirements when laid down. New-born calves have been observed when desiring to lie down to adopt the kneeling position on a site too close to a wall, but, presumably realising that they cannot complete the act of lying down because of the wall's proximity, they resume the standing position. From this it may be inferred that it was after the calf had knelt down that it realised it could not complete the act, so that probably calves have an innate ability to judge distance in relation to their body size but do not exercise this faculty until immediately before it is required, i.e. until after they have assumed the kneeling position and before assuming the final lying position. Presumably, therefore, what the calves have to learn is to kneel on a site the required distance from a wall.

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(vi) Cattle lying down on sloping ground invariably lie with the feet down-hill. This would appear to be innate as I have never observed even young calves to depart from this rule.

(vii). A cow in season being driven along a highway was observed to reverse its hind quarters into a barred gate, on the other side of which a bull was standing.

Lashley and Russell (1934) found that rats reared in the dark could judge the distance between themselves and a platform, on to which they wished to jump, just as well as rats reared normally and concluded that ability to judge such distances was innate. It is clear that further investigation would be required to determine completely what is innate and what is learned in the ability of cattle to appreciate spatial relationships.

(D) Use of Previous Learning in New Situations

Maier and Schneirla (1935), dealing with " Higher Mental Processes ", state that animals are able to reorganize experience, which they have acquired in learning, and may use that experience to make possible unlimited patterns of response. Probably the incident described above under the heading " (C) Appreciation of Spatial Relationships (i) " was an illustration of such ability. The cows knew from experience that the electric fence was a barrier to direct progress in the direction of the unloaded cattle, but that the way was clear down to the roadway (X to Y in photograph 7). They knew also from past experience that other strange cattle on seeing them would come towards them and these items of knowledge enabled the cows to contact at the earliest moment the stranger cattle.

The following complex behaviour pattern is one such as is quite commonly met in dealing with large domestic animals. An attendant wishes to get a heifer, free in an exercise yard, back into its own loose-box at the end of its exercise yard. He drives the animal towards the door of the box, but at the last moment, instead of entering, it dashes around the attendant and escapes into the open yard again, often kicking up its heels in apparent exultation. This may be repeated several times until the attendant resorts to other mehods of achieving his objective. Thus the method of avoiding being hemmed in such as is described under C (ii) above is combined with playful galloping down the yard, a pattern of behaviour which these cattle often engaged in.

Discussion

It has been observed that all calves learn quickly to find the site of their dam's udder whereas only an occasional animal learned to open doors, and this an accomplishment attained to only after a long experience of one environment. The probable reason for this difference lies in the aid given by the thigmotropic behaviour of the new-born calf which behaviour guides the calf repeatedly to the udder where it repeatedly receives an immediately appreciated reward. On the other hand the chance pushing across of the door bolt would have to be followed by chance pushing open of the door before the reward of ability to escape would be obtained, and as the animal has no innate guiding mechanism to lead it repeatedly to the situation where it will perform these two actions it does not get

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repeated opportunities to learn. The calf's learning to drink milk from a bucket comes into much the same category as the calf's finding of its dam's udder. The attendant guides the hungry calf to the source of milk on repeated occasions and as often is the calf rewarded, so again ideal conditions for learning are provided. This is an example of the calf adapting itself to new conditions—namely, feeding from a bucket. So also the ability to learn to profit from social grooming or from being groomed by a person all provide evidence of ability to adapt to new conditions. So also cattle become habituated to many changes in their environment, e.g., to being tied up, to having their attendants walking about among them and using items of equipment when cleaning and bedding the stalls and giving the animals their food, or milking them by hand or machine. Thus learning and memory can be regarded as means of enabling the animal the better to adapt itself to its environment just as (i) structural changes, as in growing a long or a short coat or varying the size of rumen papillæ according to diet (Brownlee, 1956), and (ii) immunological responses to micro-organisms such as *Br. abortus* or *Mycobacteria* are means to that end.

Summary

(*a*) Incidents in the lives of cattle, indicating that they have the faculties of (i) learning; (ii) memory; (iii) appreciation of spatial relationships; and (iv) ability to use previous experience in new situations, have been recorded.

(*b*) The reasons for the ease with which a calf learns the site of its dam's udder and the difficulty with which heifers learn how to open doors are discussed.

(*c*) Learning and memory are regarded as faculties which enable the animal to adapt itself more advantageously to its environment and thus serve towards the same end as do structural and immunological adaptations.

(*d*) An instance of what was probably displacement behaviour is recorded.

Acknowledgements

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PLATE I

(*Article by Brownlee, page* 407)

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PLATE II

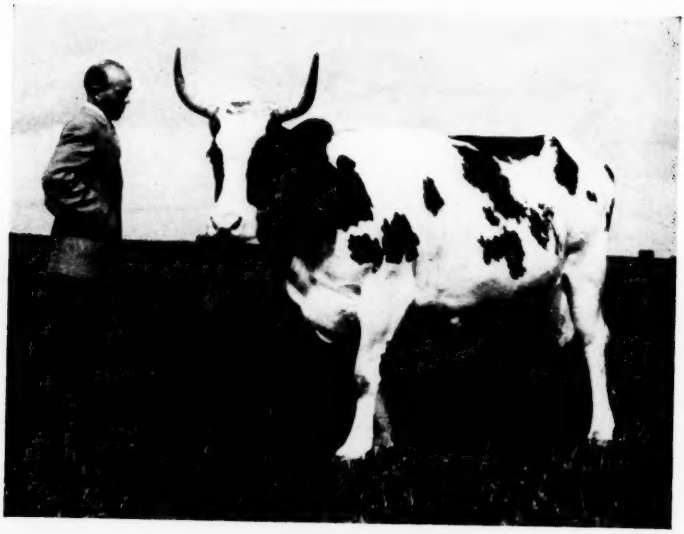

Fig. V

Fig. VI

(*Article by Brownlee, page* 407)

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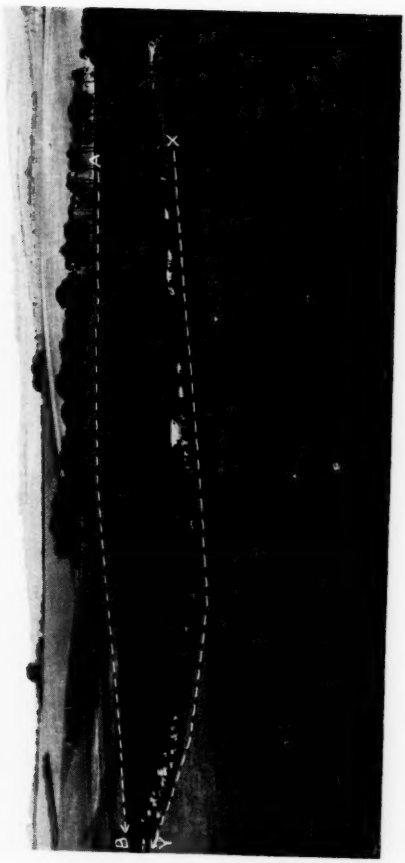

Fig. VII

(*Article by Brownlee, page* 407)

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PLATE IV

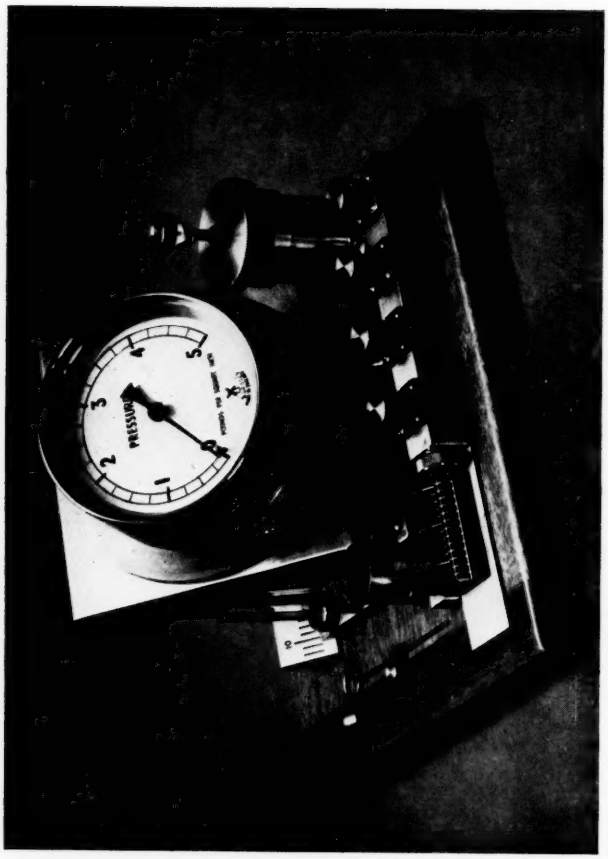

Fig. 1

(*Article by Scott-Blair, page* 417)

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MORE EARLY PREGNANCY TESTS FROM STUDIES OF BOVINE CERVICAL MUCUS

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Introduction

IN an earlier paper (Scott Blair and Glover, 1955) it was shown that the consistency of bovine cervical mucus as measured in an instrument called the "Consistometer" was, in general, greater from pregnant than from non-pregnant cows; and that, excluding a few pathological cases (about 5 per cent), pregnancy could, by this means, be correctly diagnosed in 77 per cent cases, 4 weeks after conception and in 87 per cent cases after 5 weeks, rising to 96 per cent if cows which had been previously sampled at 4 weeks were excluded. It was pointed out that the choice of the critical level (C) for the figure ($Pt^{\frac{1}{4}}$) given by the Consistometer would doubtless be improved as a result of further experiments and that the initially chosen value of $C = 9$ lb./in^2.sec$^{\frac{1}{4}}$ was probably too high. Moreover, the conclusions were based on a not very large number of tests.

The purpose of the present paper is to present further data which suggest modified values for C and to show that, taking all the experiments together, the level of success at four weeks, quoted in the earlier paper, can now be surpassed. An even simpler test, referred to in the earlier paper, in which dried mucus is examined under the microscope, will also be considered.

A point concerning nomenclature should be mentioned. In the earlier paper, the term "consistency" was briefly discussed and it was pointed out that this word has no precise dimensional connotation. The resistance offered to extrusion from a capillary tube by a material under pressure in the Consistometer is certainly a measure of its consistency; yet it would be unwise to *define* the parameter $Pt^{\frac{1}{4}}$, which is a measure of this resistance, as "consistency", since such a course would seem to preclude the use of this term for other equally valid measures and also for materials which cannot be extruded in this manner. It is therefore proposed that $Pt^{\frac{1}{4}}$ be called an "Index of consistency" which indeed it is. Other "indices" apply to other conditions and materials.

Further Experiments

The same herd of cows has been tested during a further period of two and a half years, since the previously published work was completed. Some of the cows are new additions, but many are the same and some have now been tested in two or three pregnancies. The cows were Shorthorns and Friesians, with a few Guernseys. The ratio of Shorthorns to Friesians fell from 2.1 in the earlier experiment to 1.2 in the later. The small proportion of Guernseys remained almost unchanged. The methods of taking samples and doing the tests and the conventions for selecting data for determining the efficiency of the pregnancy diagnoses are described in the earlier paper and are unchanged.

A study of the accuracy of the Consistometer and of its use as a viscometer has been published by Scott Blair and Glover (1956a) and an improved model of

the instrument, shown in Fig. I, has been designed. (These Consistometers are now obtainable from Messrs. Arnold & Sons, 54 Wigmore Street, London, W.1.)

The importance of taking a representative sample from the correct position in the cervix and of ensuring careful mixing before sub-sampling should again be emphasized. Tests were discarded as "pathological" when either (1) the rectal temperatures exceeded 102.5° or (2) a veterinary examination later revealed conditions likely to have invalidated the test.* (See previous paper.) In the second part of the experiment 9 out of 351 cases (2.5 per cent) were discarded as pathological.

The criterion value for the index of consistency has now been adjusted in the light of the last two years' experience, as was expected; and further, it has

TABLE I

The results of pregnancy diagnosis using the "Consistometer"

	Non-pregnant		Pregnant. (days after conception)					
Number of:-	Not served	served	18-19	24-25	27-29	about 35	about 42	Retests
Shorthorns correct	56	21	8	14	32	21	6	38
" incorrect	1	5	1	1	4	1	0	4
Friesians correct	30	16	13	13	26	22	4	33
" incorrect	4	8	4	2	1	1	0	1
Guernseys } correct	12	8	2	1	3	1	0	4
and crosses } incorrect	0	2	1	2	0	4	0	0
Totals:-								
No. of correct diagnoses	98	45	23	28	61	44	10	75
" " incorrect "	5	15	6	5	5	6	0	5
% correct	95	(75)	80	85	92	88	100	94

All non-pregnant % correct: 88

Total number of tests: 431
" " " pregnancies 188

been found advantageous, in this herd, to use a different criterion for Shorthorns from that used for Friesians. For the few Guernseys available, it has seemed best for the present to use the same criterion as for Shorthorns, and this value is used also for two Shorthorn-Friesian cross cows. For Friesians, all data have now been adjusted to a value of $C = 2.5$ and for other breeds to 5.0 lb./in^2.sec$^{\frac{1}{2}}$. At another farm, however, where a much smaller experiment was done, the distinct impression was formed that the value $C = 2.5$ was too low for Friesians. Further experiments alone will decide, although only relatively small differences in efficiency are associated with these changes.

At first sight, these might appear to be large, yet the number of samples for which the value of $Pt^{\frac{1}{2}}$ lies between, say, 5.0 and 2.5 is small. For example, in the later experiment, out of 134 tests on Shorthorns, the mean value of $Pt^{\frac{1}{2}}$ was between 2.5 and 5.0 on 9 occasions (7 per cent). Of 144 Friesian tests, 11 were within this range (8 per cent). These figures include tests done only 18-19 days after conception. It must also be remembered that, quite apart from those samples whose

* This includes observed cases of retained corpora lutea in which the secretions are, unfortunately, often indistinguishable from pregnant samples; but there were only three such cases.

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consistency is either too high or too low to be measured, the instrument itself covers a wide range of $Pt^{\frac{1}{4}}$ from about 0.2 to 60.0 units.

In the last two years tests have been made in very early pregnancy. The results, combined with those re-calculated from the earlier experiment, are given in Table I.

Discussion on Table 1

It will be remembered that samples taken from recently tested cows, in early pregnancy, sometimes gave misleading results. On the other hand, it is often advisable to do a re-test, usually at about 30 days, following a test in very early pregnancy. The re-tests are listed separately in the last column of the table. Their level of success is very much higher than might have been expected from the earlier experiments.

It will be seen that about 25 per cent of cows which had been served but which were later found to be non-pregnant, gave positive tests at some earlier stage, though these include tests at 18-19 days after conception which, as is clear from the table, are unreliable.

In one case it was evident, on veterinary examination, that a fœtus had been lost, in others little or no evidence remained. For this reason, the low figure given in Table I is in parenthesis. About 5 per cent of unserved cows give incorrect tests, presumably due to hormonal imbalance (they are almost always subfertile); and it may well be that a few positive tests in early pregnancy are similarly "incorrect". In view of the figures, it seems likely that, in most of these cases (about 9 per cent of the pregnancies studied) a fœtus has been lost. This seems to happen more often with Friesians than with Shorthorns. The possibility of an unnoticed retained corpus luteum cannot always be ruled out, however, since this sometimes has a toughening effect on the secretions. Two cows gave positive tests at 18 or 24 days, but were not examined by rectal palpation until very much later (over eight weeks after conception) and were finally found to be non-pregnant. Since there is no information about their earlier condition, they are excluded from the table.

The high level of success of repeat tests suggests that, when desirable, a second test would be worth while. Ordinarily, pregnancy tests are not claimed to predict whether the pregnancy will hold, but it has been shown (Glover and Scott Blair, 1953) that the index of consistency tends to fall *before* the loss of a fœtus, which thus may be foretold sometimes, even if not prevented.

The degree of confidence in the results of any individual test must depend on how far the index of consistency differs from its criterion value. For scoring purposes, however, as in the earlier experiment, all values were accepted except in the very few cases when the three or four readings from which $Pt^{\frac{1}{4}}$ was averaged fell fairly symmetrically on both sides of the criterion value (e.g., readings of 4.5, 5.0 and 5.5 for a Shorthorn). In such cases the test was discarded and repeated a few days later, since now the disadvantages of a re-test do not appear to be as serious as was supposed previously.

A critic has suggested (privately) that all such cases, as well as all pathological cases now excluded from the table, should be listed as "failures". This view cannot be accepted, however, since in practice it is much more serious to tell

a farmer that his cow is pregnant when she is not (or vice versa) than to tell him that the test must be repeated in a few days' time; or, at worst, that he must wait for a few weeks, as he has hitherto always done, until an examination by rectal palpation becomes possible. Such indeterminate cases would constitute a serious objection to the test only if they occurred frequently: fortunately they are rare.

In general, the test appears to work slightly better for Shorthorns than for Friesians both in pregnancy and non-pregnancy, especially the latter, though this is partly due to the greater number of Friesian (inferred) fœtal losses. Taking all tests together (including repeats and 18-day tests) the general level of success for Shorthorns is 91.5 per cent and for Friesians 84.5 per cent. The level of correct diagnoses was higher at 28 than at 35 days, but it will be seen that 3 of the 7 failures at 35 days were Guernseys and crossbreds, in which the diagnosis is less sure, partly through lack of experience. It is not known whether this apparent fall in consistency after 28 days is significant or not. One Friesian-Shorthorn cross was diagnosed wrongly at 35 days using the Shorthorn criterion of 5.0, but the test would have been correct had the Friesian criterion (2.5) been applied.

As in the former experiment, cows which gave unaccountable wrong diagnoses, whether pregnant or non-pregnant, although not obviously diseased, had a poor conception rate. This was presumably due to hormonal imbalance.

Effects of Age, Body Temperature and Ambient Temperature

There is no significant correlation between age of cow and consistency of secretion, but the test probably fails rather more often with older cows.

Rectal and shed temperatures were taken during almost the whole of the second experiment. Three of the nine cases discarded as "pathological" were taken out of the experiment because body temperatures were higher than the assumed maximal normal (102.5°). A somewhat low correlation (.153) was found* on 489 pairs of body and shed temperatures, but an interesting relation was noted between the change in shed temperature between each two sampling days (this varied from 1 to 4 or 5 days) and the average rise or fall in cow temperatures on the two days. Thus there were 47 cases when cow and shed temperatures both increased, 49 when both decreased; whereas cow temperatures increased only 29 times with a falling shed temperature and decreased only 33 times with a rising shed temperature. Omitting the few cases where there was no temperature change either in the shed or in the cows, this means that shed and cow temperatures varied in the same direction on 60.5 per cent of occasions and in opposite directions on only 39.5 per cent of occasions.

The effects of large variations in ambient temperature on the body temperature of cows have often been reported, but little or no information appears to be recorded under the ordinary climatic conditions of Southern England.

Crystal Structure of NaCl in Dried Mucus

We are indebted to Prof. B. Zondek for the suggestio (1954)† that the

* We are indebted to Miss Z. Hosking for calculating this figure.

† For gynæcological applications and references see Zondek (1954) and for cattle, Higaki and Awai (1953), Pozo Lora (1954, 1955) and Coluzzi and Battistacci (1955), to which papers the reader is referred for details of the method. For the present authors' preminary data, see Scott Blair and Glover (1956, 1957).

presence or absence of fern-like structures of NaCl crystals in mucus dried on a glass plate might serve as an indication of bovine pregnancy.

Most of the secretions tested in the Consistometer during the last two years were afterwards smeared on to glass slides and dried; then scored under the microscope as showing (1) very marked fern structures; (2) marked fern structure; (3) some ferns; (4) traces of ferns; (5) no ferns, traces of cellular structure; (6) definitely cellular; (7) highly cellular. Taking scores 1-4 as indicating non-pregnancy and 5-7 for pregnancy, the results are shown in Table II.

The results may be compared with those of Coluzzi and Battistacci (1955), who, getting uncertain diagnoses in pregnancy tests on over 30 per cent of their 136 cows, conclude that the method is not practicable. The " uncertainties " of the Italian work do not appear, our tests being generally either right or wrong.

TABLE II

Pregnancy tests from fern structures of NaCl crystals in undiluted secretions

Number of:-	Non-pregnant		Pregnant. (days after conception)				
	Not served	served	18-19	24-25	27-29	about 35	Retests
Shorthorns correct	17	11	10	13	14	4	22
" incorrect	6	7	2	2	3	2	3
Friesians correct	15	11	14	14	11	17	22
" incorrect	4	8	3	1	0	1	0
Guernseys and crosses correct	6	6	1	2	2	1	2
Guernseys and crosses incorrect	1	2	1	1	0	3	0
Totals:-							
No. correct	38	28	25	29	27	22	46
No. incorrect	11	17	6	4	3	6	3
% correct	78	(62)	81	38	90	79	94

It will be seen that the tests here reported show considerable promise but that the " criterion " is wrongly placed, since fair accuracy in very early pregnancy is obtained at the expense of many mistakes with non-pregnant animals. Attempts to correct the criterion by including group 5 or groups 5 and 6 as non-pregnant, made matters worse, however, and it seemed best to maintain the simple criterion of ferns for non-pregnancy and no ferns for pregnancy; but to try to increase fern production for any given hormonal conditions. An attempt was made to do this by diluting the secretion with water. Small volumes of mucus, measured from the capillary tube of the Consistometer, were diluted with approximately 2 and 3, and later 6, and 10 equal volumes of distilled water and, after gentle mixing, left in a small closed container over night. The following morning they were smeared onto microscope slides and, after drying, examined microscopically. The crystal structures in the undiluted and diluted samples were compared. The results show that increasing dilution certainly increases the pro-

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duction of ferns. Unfortunately, the cows available at the time were not suitable for a reliable application of these results as a test for pregnancy, but they suggest that at least a ten-fold dilution is necessary before any improvement in diagnosis is apparent.

Other methods, such as buffering the secretions to rather a high pH, might be tried, but the advantages of the fern test lie in its speed and simplicity and the introduction of any form of pretreatment would make the test no quicker or simpler than the use of the Consistometer.

Ultra-violet Absorption Spectra

In the earlier paper it was reported that the absorption of ultra-violet light at a wave-length of about 278 $m\mu$ is relatively greatest in secretions from pregnant cows, less in dicestrus and least at cestrus. Unfortunately the quick method for doing this test, using undiluted and uncentrifuged samples, has not, in the long run, proved satisfactory, probably because of difficulties in measuring path-lengths $\sim$0.1 mm. accurately. It is hoped to do further experiments on diluted and centrifuged samples for research purposes, but it does not seem at present that the method is likely to be sufficiently rapid for use as a practical test of pregnancy.

Conclusions

The authors are often asked whether these two tests, and especially the more accurate Consistometer test, will prove useful in the practical diagnosis of pregnancy as distinct from their value as research tools. This is a question which it is not yet possible to answer. Though a few tests have been done elsewhere, large-scale experiments have, so far, been made on one herd only of about 150 cows, all under similar management. The criterion level for the Index of Consistency seems to depend somewhat on breed. Observations during the course of this research have suggested that it may possibly also depend on climate and management. When such variations are better understood, a higher level of success may well be attained.

As tests for pregnancy, both the Consistometer and the crystal structure observations are indirect in that they depend on hormonal levels and may prove misleading under abnormal hormonal conditions. Many biological and, incidentally, all psychological tests, are indirect in this sense; yet many have proved their usefulness. Among the former, levels and tolerances of blood sugar, levels of blood urea, hormone concentrations in (human) urine, and blood and intraocular pressure measurements, all contribute to medicine, yet none, taken alone, is invariably indicative of the condition it is supposed to diagnose, especially in borderline cases. The question is not whether the Consistometer will ever diagnose pregnancy wrongly—it certainly will; it is rather whether such tests can, in practice, help the veterinarian to predict with, say, 90 per cent assurance whether a cow is pregnant some weeks before he can reach the same level of assurance by rectal examination alone. There are even cases where rectal palpation cannot be certain for as long as 60-70 days. The authors' hope is that the new tests can help the veterinarian; further experiments will decide and it is hoped that these will be undertaken by other investigators working under different conditions of climate and herd management.* It must be stressed, however, that careful

* The authors are happy to hear that an experiment on a larger scale is planned in U.S.A.

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veterinary supervision is important for such trials. Since the usual causes of failure by veterinary examination and by the Consistometer are quite different, the former being generally anatomical and the latter hormonal, the two methods should prove complementary in the hands of the veterinary surgeon.

Though it is probable that the present methods of sampling and testing will remain unchanged, the establishment of the best criterion values must depend on a very much wider experience than is available at present.

Serious consideration must also be given to the question of the best time for testing if it is to be useful for practical purposes. While high accuracy is obtained at 28 days after service, it seems that a relatively large percentage of these early pregnancies are not maintained. Most of these losses probably occur at an early stage and it might be more practical to do the test somewhat later, when the risk of fœtal loss may be less, even if the accuracy is slightly lower.

Summary

The " consistency " method for the diagnosis of bovine pregnancy described in an earlier paper has been applied to many more cases and the criterion of diagnosis has been adjusted. Excluding a few pathological cases (2½ per cent), pregnancy is best diagnosed at 28 days after conception, when a level of 92 per cent correct has been reached.

In non-pregnant unserved cows, the test fails in about 5 per cent of cases, almost all of which are associated with sub-fertility. In served cows, later found to be non-pregnant, some 25 per cent appear to be pregnant when tested (including tests as early as 18 days). Probably this is frequently due to early fœtal deaths. In most other cases where the test fails with pregnant cows consistently there is a history of sub-fertility.

The presence of fern-like structures of crystals of sodium chloride in dried mucus from non-pregnant cows, and their absence in pregnancy may be misleading if used for diagnostic purposes. An attempt to shift the criterion, when the fern-like and cellular structures are scored, did not improve the diagnoses, but suggested that diluting or pre-treating the mucus, so as to increase fern production, may lessen the number of mistakes among non-pregnant cows.

Possible practical applications of these two pregnancy tests are discussed and the need for further experiments, on other herds, is stressed.

Acknowledgements

We wish to acknowledge the help of Mr. D. R. Melrose, M.R.C.V.S., of the Reading Cattle Breeding Centre, who made the pregnancy diagnoses by rectal palpation and gave much valuable advice. Our best thanks are also due to Mr. B. B. Brown for helpful discussions.

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INFUSION AND ANALEPTIC THERAPY
PART 2

By A. M. HARTHOORN, D.V.Sc., F.R.C.V.S.

Their respective values in the resuscitation of dogs from overdosage of pentobarbitone sodium

Key to Protocols, I

(Numbers refer to Protocols)

Therapy.

Saline or Ringer solution alone 2 and 7 (Non-survival experiments, group A).

Saline or Ringer after previous analeptic therapy 1, 5, 8, 9 and 10.

Saline, Ringer or Dextraven alone 11, 12, 13, 16 and 17.

(Survival experiments, group B).

Saline given twice 8 and 9.

Analeptic alone 4, 14 and 15.

Analeptic after previous Saline 3, 5 and 6.

Results.

Response before termination of infusion 11, 12, 13 and 10 (3 and 7 partial).

Response by artificial respiration following saline or Ringer therapy 2, 7, 9 and 17.

Convulsions due to analeptic 1, 8, 9 and 10.

Convulsions without respiration 1 and 8.

Protocols: Part I

(1) Mongrel bitch, body weight 10.5 kg. Pentobarbitone sodium administered to cessation of respirations, followed by 20 per cent. of dose used. 15 minutes of artificial respiration, followed by 2 minutes pause. No respiratory response after a further 15 minutes artificial respiration, 1.0 mg/kg. Picrotoxin, after 15 minutes no respiration.

1.0 mg/kg. Picrotoxin, after 15 minutes no respiration.

1.0 mg/kg. Picrotoxin, after 15 minutes no respiration.

1.0 mg/kg. Picrotoxin, after 15 minutes no respiration.

2.0 mg/kg. Picrotoxin, after 15 minutes no respiration.

Picrotoxin convulsions. 20 c.c./kg. Physiological saline. After 10 minutes (post infusion) sufficient respirations to maintain life.

Destroyed after 30 minutes on account of convulsions.

(2) Mongrel dog (male), body weight 8.1 kg. Pentobarbitone sodium administered to cessation of respirations, followed by 20 per cent. of dose used. 15 minutes of artificial respiration, followed by no respiratory response. None after a further 15 minutes artificial respiration. 20 c.c./kg. Ringer solution. After 15 minutes, respirations at the rate of 2 per minute, but considerable cyanosis. Artificial respiration for 30 minutes. Respirations 3 per minute, but deeper and sufficient. Respirations maintained.

(3) Mongrel bitch, body weight 20 kg. Pentobarbitone sodium administered to cessation of respirations, followed by 20 per cent. of dose used. Blood pressure rather low and 50 gamma noradrenalin administered intravenously. Blood pressure

maintained at normal. After 15 minutes artificial respiration no respiratory response. 10 c.c./kg. Physiological saline. Slight respiratory movements. 20 c.c./kg. Physiological saline, respiratory movements, but not sufficient for survival. Cardiozol 8 mg/kg. Respirations 3 per minute.
Respirations maintained.

(4) Mongrel dog (male), body weight 10.3 kg. Pentobarbitone sodium administered to cessation of respirations, followed by 20 per cent of dose used. After 15 minutes artificial respiration no respiratory response. None after a further 15 minutes.

Picrotoxin 1.0 mg/kg., after 15 minutes no respiration.

Picrotoxin 1.0 mg/kg., after 15 minutes no respiration.

Cardiozol 6.0 mg/kg., after 15 minutes no respiration.

Cardiozol 6.0 mg/kg., after 15 minutes respirations 2 per minute.

After 30 minutes respirations 1 per ¾ minute, cyanosis.

Cardiozol 6.0 mg/kg., respirations after 5 minutes 4 per minute.

After 60 minutes respirations ceased.

(5) Mongrel dog (male), body weight 7.8 kg. Pentobarbitone sodium administered to cessation of respirations, followed by 20 per cent. of dose used. After 15 minutes artificial respiration, no respiratory response. None after a further 15 minutes.

Picrotoxin 1.0 mg/kg., after 15 miuutes no respiration.

Picrotoxin 1.0 mg/kg., after 15 miuutes no respiration.

Cardiozol 6.0 mg/kg., after 15 minutes no respiration.

20 c.c./kg. Ringer solution. 2 minutes after end of infusion respirations one per ¾ minute. After 15 minutes artificial respiration 2 per minute.

Cardiozol 6.0 mg/kg., respirations 5 per minute.

Respirations maintained.

(6) Mongrel bitch, body weight 11.4 kg. Pentobarbitone sodium administered to cessation of respirations, followed by 20 per cent. of dose used.

After 15 minutes artificial respiration no respiratory response.

None after a further 15 minutes.

Physiological saline solution 20 c.c./kg.

20 minutes from commencement respirations 3 per minute, but insufficient to maintain life.

Picrotoxin 1.0 mg/kg., after 15 minutes respirations 2 per minute, but deeper.

Picrotoxin 1.0 mg/kg., after 15 minutes respirations 3 per minute. Adequate.

Respirations maintained.

(7) Mongrel dog (male), body weight 9.2 kg. Pentobarbitone sodium administered to cessation of respirations followed by 20 per cent. of dose used.

After 15 minutes artificial respiration no respiratory response.

None after a further 15 minutes.

Physiological saline 20 c.c./kg., given in 10 minutes.

Respirations 1 per minute. Cyanosis. Artificial respiration for 15 minutes, respirations 2 per minute. Cyanosis.

Artificial respiration for 15 minutes, respirations 5 per two minutes, but deeper and sufficient.

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Respirations maintained.

(8) Mongrel dog (male), body weight, 11.3 kg. Pentobarbitone sodium administered to cessation of respirations, followed by 20 per cent. of dose used.

After 15 minutes artificial respiration no respiratory response.

None after a further 15 minutes.

Cardiozol 4 mg/kg., after 15 minutes no respiration.

Cardiozol 4 mg/kg., after 15 minutes no respiration.

Cardiozol 4 mg/kg., after 15 minutes no respiration.

Cardiozol 4 mg/kg., after 15 minutes no respiration.

Cardiozol 4 mg/kg., after 15 minutes no respiration slight twitching.

Physiological saline 20 c.c./kg. in 10 minutes, respiration one per $1\frac{1}{2}$ minutes.

After 15 minutes artificial respiration, respiration one per $\frac{3}{4}$ minute.

Cyanosis but sufficient to maintain life.

After one hour respirations 2 per minute.

Pentobarbitone sodium administered to cessation of respirations.

After 15 minutes artificial respiration, no respiratory response.

Physiological saline solution 20 c.c./kg. 15 minutes after commencement of infusion, respirations one per minute. Adequate.

Respirations maintained.

(9) Mongrel dog (male), body weight 9.3 kg. Pentobarbitone sodium administered to cessation of respirations, followed by 20 per cent. of dose used.

After 15 minutes artificial respiration no respiratory response.

None after a further 15 minutes.

Cardiozol 4 mg/kg., after 15 minutes no respiration.

Cardiozol 4 mg/kg., after 15 minutes no respiration.

Cardiozol 4 mg/kg., after 15 minutes no respiration.

Cardiozol 4 mg/kg., some attempts at respiration, which disappeared after 20 minutes, feeble convulsions.

Physiological saline 20 c.c./kg. 15 minutes after commencement of infusion respirations one movement per minute but insufficient to maintain life.

Artificial respiration for 30 minutes. Respirations 2 per minute, adequate.

After one hour respirations 5 per 2 minutes.

Pentobarbitone sodium administered to cessation of respirations.

After 15 minutes artificial respiration no respiratory response.

Physiological saline solution 20 c.c./kg. 25 minutes after commencement of infusion, respirations one per minute. Adequate.

Respirations maintained.

(10) Mongrel bitch, body weight 12.0 kg. Pentobarbitone sodium administered to cessation of respirations, followed by 20 per cent. of dose used.

After 15 minutes artificial respiration no respiratory response.

None after a further 15 minutes.

Cardiozol 4 mg/kg., after 15 minutes no respiration.

Cardiozol 4 mg/kg., after 15 minutes no respiration.

Cardiozol 4 mg/kg., after 15 minutes no respiration.

Cardiozol 4 mg/kg., respiration one per minute.

After 15 minutes respirations less than one per minute.

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Cardiozol 4 mg/kg., respirations one per minute plus. Adequate but slight convulsions.

After 30 minutes no convulsions, but respirations less than one per minute. Cyanosis. Inadequate.

Physiological saline 20 c.c./kg. 20 minutes after commencement of infusion respirations one per minute. Adequate.

One hour later respirations 2 per minute.

Respirations maintained.

Key to Protocols, II

Saline Solution administered 1, 3, 6, 7, 8, 9, 10, 13 and 17. Ringer Solution administered 2 and 5. Dextraven administered 11, 12 and 16. Picrotoxin administered 1, 4, 5, 6, 14 and 15. Cardiozol administered 3, 4, 5, 8, 9 and 10. Picrotoxin and Saline administered 1 and 6. Cardiozol and Saline administered 3, 8 and 10. Cardiozol and Picrotoxin administered 4 and 5. Picrotoxin, Cardiozol and Ringer administered 5.

Protocols: Part II

(11) Mongrel bitch, body weight 10.5 kg. Pentobarbitone sodium given to loss of pedal reflex.

After 15 minutes more given to cessation of respirations.

After 15 minutes no respirations. 20 per cent. of total original dose given.

No respirations after 15 minutes artificial respiration (by hand).

Dextraven infusion commenced.

After 10 minutes and 7 c.c./kg., no respirations.

After 20 minutes and 14 c.c./kg., respirations 10 per minute, but very shallow. Cyanosis.

Artificial respiration stopped.

After 30 minutes and 20 c.c./kg., respirations 7 per minute and normal.

Infusion ceased. Cyanosis very slight.

Survived.

(12) Mongrel bitch, body weight 2.5 kg. Pentobarbitone sodium given to loss of pedal reflex; after 15 minutes more given to cessation of respirations.

After 15 minutes slight respiration movement but no true respiration. 20 per cent. of total original dose given. After 15 minutes no respiration.

Dextraven infusion commenced.

After 7 c.c./kg. and 12 minutes, respirations 4 per minute, but very shallow. Cyanosis.

After 15 c.c./kg. and 30 minutes (approx.) respirations 4 per minute but deeper. Colour almost normal. Artificial respiration ceased.

After 20 c.c./kg. respirations 4 per minute but deep. No cyanosis.

Infusion ceased. 2 hours later respirations 4 per minute, and deep.

Survived.

Infusion and Analeptic Therapy

(13) Mongrel bitch, body weight 14.7 kg.

Pentobarbitone sodium given to loss of pedal reflex.

After 15 minutes more given to cessation of respirations.

After 15 minutes no respirations, 20 per cent. of original total dose given.
Physiological saline infusion commenced.
After 10 minutes and 5 c.c./kg., no respirations.
After 20 minutes and 10 c.c./kg., no respirations.
After 30 minutes and 15 c.c./kg., 3 respirations per minute.
Cyanosis, but sufficient to maintain life.
Artificial respiration ceased.
After 40 minutes and 20 c.c./kg., respirations 7 per minute.
Slight cyanosis. Infusion ceased.
After 30 more minutes respirations 9 per minute.
Survived.
(14) Mongrel dog (male), body weight 7.1 kg.
Pentobarbitone sodium given to loss of pedal reflex.
After 15 minutes more given to cessation of respirations.
After 15 minutes slight respiratory movements but no true respirations. 20 per cent. of original total dose given.
Picrotoxin 1.0 mg/kg., respiratory movement 2 per minute. Cyanosis.
After 15 minutes Picrotoxin 1.0 mg/kg., respiratory movements 2 per minute. Cyanosis.
After 15 minutes Picrotoxin 1.0 mg/kg., respirations 3 per minute.
Sufficient. Artificial respiration ceased.
After 15 minutes Picrotoxin 1.0 mg/kg., respirations 4 per minute.
Adequate.
Six hours later found dead.
(15) Mongrel bitch, body weight 10.5 kg.
Pentobarbitone sodium given to loss of pedal reflex.
After 15 minutes more given to cessation of respirations.
After 15 minutes no respiratory movements. 20 per cent. of original total dose given.
Picrotoxin 1.0 mg/kg., no respiratory movements.
After 15 minutes Picrotoxin 1.0 mg/kg., no movements.
After 15 minutes Picrotoxin 1.0 mg/kg., no movements.
After 15 minutes Picrotoxin 1.0 mg/kg., 3 respiratory movements per minute.
After 15 minutes Picrotoxin 1.0 mg/kg., 3 respirations per minute.
Artificial respiration ceased.
After 15 minutes Picrotoxin 1.0 mg/kg., 3 respirations per minute.
After 30 minutes respirations 3 per minute but shallower 1.0 mg. Picrotoxin given.
Respirations 4 per minute. 4 hours later found dead.
(16) Mongrel bitch, body weight 2.5 kg.
Pentobarbitone sodium given to loss of pedal reflex.
After 15 minutes more given to cessation of respirations.
After 15 minutes no respirations. 20 per cent. of original total dose given.
Dextraven infusion commenced after 15 minutes (approx.).
After 10 c.c./kg. attempts at respiration, but failure to draw breath.
After 15 c.c. and 20 minutes respirations 4 per minute. Cyanosis.

Artificial respiration ceased.
After 20 c.c. and approx. 35 minutes respirations 5 per minute and very deep.
Infusion ceased.
Survived.
(17) Mongrel bitch, body weight 14.7 kg.
Pentobarbitone sodium given to loss of pedal reflex.
After 15 minutes more given to cessation of respirations.
After 15 minutes slight attempt at respirations. 20 per cent. of original total dose given.
After 15 minutes (approx.) Physiological saline infusion commenced.
After 10 minutes and 7 c.c./kg., no respirations.
After 20 minutes and 15 c.c./kg., respiration movements.
After 30 minutes and 20 c.c./kg., 3 shallow respirations per minute.
Infusion ceased.
After 45 minutes respirations 3 per minute, but deeper. Cyanosis (medium).
Artificial respiration ceased.
After 1 hour respirations 4 per minute. Cyanosis slight.
Survived.

Discussion of Protocols

In the course of the experiments with various means of resuscitation of anæsthetised animals, the results of the laboratory trials are recorded in the protocols of this paper, a method has been devised, which seems to hold some advantages over that of pure analeptic therapy. It is not suggested that the method of hæmolavage is able to supplant analeptic therapy, or that many cases of anæsthetic overdosage may not respond adequately to analeptic therapy alone. The method that has been evolved in the course of the experiments, however, has the advantage that the results obtained seem to be rather more certain of continued effect than when they are obtained solely through the agency of analeptics. There seems to be some case also for the utilisation of fluid therapy as a supporting measure when the results obtained through the agency of analeptics are insufficient.

These protocols are a demonstration of a repeated experience and observation in general practice: (*a*) that it is often extremely difficult to cause over-anæsthetised subjects to revive with the use of analeptics alone, (*b*) that enormous amounts of time must be devoted to the regular administration of intravenous doses of analeptic, (*c*) that even after apparent recovery has been effected, the anæsthetic agent may be broken down more slowly than the analeptic, and the patient is found dead some hours later, when, in the confidence of the recovery having been effected, the patient has been removed from the operating theatre and left unattended. The knowledge that this may happen even in those cases where the continued recovery of the patient is almost a certainty makes it dangerous to leave the patient without access to expert treatment for any length of time. This may mean the "tying up" of an assistant of the principal of the practice for many hours during which he might have attended to other work. It is my actual experience that in several cases where restorative treatment had been carried out until late in the evening and when apparent complete recovery has taken place, and the veterinary staff have retired

to rest, the patient was found dead in the morning. The experiments illustrating this subject have been restricted to only a few, because with the high doses of anæsthetic used in these trials, death under this form of treatment was almost certain. These protocols show that (*a*) the recovery of a patient suffering from a large overdose of anæsthetic may be difficult to effect even when treatment is continued for several hours, if analeptics alone are used (Protocols 1 and 8: analeptic therapy for 1 hour and 15 minutes without result other than convulsions), (*b*) that if apparent recovery can be effected, it is not safe to leave the patient without the constant attention of a trained assistant.

This point, that patients may die as a direct result of the anæsthetic, even after apparent recovery has been effected by analeptic therapy, has seldom been stressed in veterinary literature. In many cases these deaths may have been attributed to other causes. Experiments such as the ones described in protocols 4, 10, 14 and 15 show that it is quite possible for animals that have been resuscitated with analeptics to revert and to die subsequently from the anæsthetic alone, i.e., the action of the analeptic is more transient than that of the anæsthetic. This means that, in practice, any animal whose respiration has been restored with analeptics after barbiturate overdosage, cannot be left alone, with safety, until it has completely recovered from the anæsthetic. It has been shown also (Protocols 11, 12, 13, 16 and 17) that, once an animal has been resuscitated with the use of hæmolavage, it will not die of the direct effects of the anæsthetic overdosage.

Taken to its logical conclusion, this implies that analeptics can never be used satisfactorily. Even if hæmolavage is used as an adjuvant, one could not be certain that after the effect of the analeptic had worn off, the amount infused would be sufficient for recovery; and renewed respiratory failure might still occur. This argument, however, would only hold good in cases, surely rare in veterinary practice, where the animal in question is suffering from accidental barbiturate poisoning with an unknown and possibly enormous amount of ingested barbiturate. In these tests the amount injected is probably far greater than any overdose that may be given inadvertently under practice conditions. The amount of fluid 20 c.cm./Kg.B.W., used (when tested alone) was sufficient to ensure recovery in all cases. There is the argument also that it seems to be unreasonable to suppose that, once the anæsthetic agent has been diluted in the blood stream, the added fluid could be eliminated from the body without the water-soluble anæsthetic agent. The hypothesis that the anæsthetic and fluid are excreted simultaneously appears to be substantiated by the results.

To give a hypothetical example: If we take an average sized dog of 13 kilo, we can assume that its circulatory blood volume is approximately 1,000 c.cm. Injecting 20 c.cm./kilo we infuse 260 c.cm. As the hæmatocrit value of the average dog is about 50 we are diluting the plasma by roughly one-third. In these experiments 20 per cent. of the dose originally needed to produce a state of near respiratory, and in most cases complete respiratory failure, was added after this point of failure had been reached. The dose of fluid used proved to be capable of eliminating amply this 20 per cent. from the blood stream. We may assume therefore that after the infusion of the proposed amount, it may be reasonably expected that the injected dose of anæsthetic in the blood stream will be reduced at the very least by

an *effective* amount of more than one-fifth; actually between one-third and one-fifth.

In most cases of nembutal overdosage therefore, assuming that the recommended dose of 20 c.cm./Kg.B.W. is to be infused, analeptics may be used safely in an attempt either to bring about a rapid return of spontaneous respiration or to assist the infusion in causing a more speedy resolution.

It has been mentioned previously that the experiments were performed in two batches, the first being done under laboratory conditions and the second simulated the circumstances of veterinary practice. Among other differences the infusions in the second lot were given more slowly than in the first, so that they took some 30 minutes to 40 minutes; at the appropriate speed that infusions would normally be given in practice. The protocols show that under those conditions the animal usually starts to breathe before the infusion is completed, and thus under practice conditions it might be advantageous to stop the infusion at that point; certainly there is little indication for the use of analeptics.

The second group of protocols (i.e., No. 11 onwards) give a better idea of the value of fluid infusions as an antidote to anæsthetic overdosage than the first, in which the saline solution or Ringer solution was administered at speeds which would not normally be employed. In this group the dose of analeptic, which was given after the termination of the infusion, was shown to be not necessary when the infusion is given slowly and appears only to have tided the animal over a certain time-interval, possibly that necessary for an equilibrium to be found between the concentration of anæsthetic in the blood and that present in certain tissues of the body. At the most it appears necessary, in those cases where the infusion takes an insufficient amount of time, that artificial respiration be carried out to cover the required time-interval (See protocols 2, 7, 9 and 17).

The important fact that becomes apparent from the protocols is that, whereas after analeptic therapy the patient usually becomes progressively worse after the initial stimulation has worn off (See protocols 4, 10, 14 and 15), under fluid therapy his condition certainly does not deteriorate below that obtaining a few minutes after the termination of the infusion and in fact seems to improve in the course of the next hour or so.

It also appears from the protocols that the composition of the fluid used makes little difference, as long, of course, as it is a compatible liquid isotonic with the body fluids. It seems from the protocols that there appears to be no advantage in using Ringer (See 2 and 5) over Physiological saline (See 1, 3, 6, 7, 8, 9, 10, 13 and 17). Neither does there appear to be an advantage in using Dextraven, at least as far as the dilution and ultimate elimination of the anæsthetic is concerned.

The fact, that Dextraven seems to work as well as Physiological saline solution in achieving the resuscitation may be very advantageous when the diagnosis of the patient's condition is not absolutely clear. It is shown elsewhere (Harthoorn 1955) that this solution is capable of remaining in the circulation, and is efficient in restoring the blood pressure in cases where it is necessary to augment the normal circulatory blood volume, or to increase the oncotic pressure of the blood in cases of shock. In view of the danger, mentioned earlier, associated with the infusion of crystalloid solution in conditions of circulatory imbalance, it is advisable that in

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cases of doubt a substance be used that is capable of remaining in the blood stream and akin to plasma rather than a crystalloid fluid, isotonic with the blood and body fluids, which is capable of passing out of the blood stream with great facility.

Because of the equal efficiency of Dextraven and saline solutions as the medium for resuscitation it would appear that the restoration of the patient depends on a dilution of the anæsthetic agent in the blood stream rather than on the ultimate elimination of the solution containing the anæsthetic agent from the blood stream. Although no trials were carried out with plasma substitutes other than Dextraven, there can be little reason to doubt that other substances such as plasma or serum should not be equally efficacious.

From the protocols it can be seen also that the effect of Picrotoxin tends to be more long-lasting than the effect of Cardiozol. In those experiments where a state of " cramps " was reached it seemed that possibly the animal could be brought to a state of convulsion without the respirations being stimulated. The difficulty of carrying out further therapy on an animal that is in a state of " cramps " makes it dubious whether it is worth while to persist with the administration of an analeptic such as Picrotoxin until the cramp threshold is reached. With a substance like Cardiozol, where the cramps pass off rapidly, large amounts may be given with impunity, and less care need be taken that the cramp threshold is not exceeded.

The previous administration of analeptics seems to make little difference in the speed or alacrity with which resuscitation is effected by dilution therapy. Possibly the analeptic agent is diluted in the blood stream in a manner similar to the anæsthetic agent. Subsequent administration seems also to have little value except when insufficient time has been allowed in the course of the infusion, and the time interval mentioned above must be tided over, or possibly in cases of barbiturate poisoning where the amount ingested may be enormous and where fluid administration is used rather as supportive therapy to the analeptics. When analeptic agents are used to commence respiratory movements, one cannot always be sure that the patient may not revert once more to a state of anæsthesia or insufficient respiratory activity after the effect of the analepic agent has worn off; unless the amount of anæsthetic is known to fall within small limits.

Nos. 8 and 9 are protocols of trials in which after recovery has once been effected, further anæsthetic has been administered, followed in turn by a further infusion of 20 c.c. per kilogram body weight. These two protocols have little practical value, except that they do indicate that in conditions where the circulation is normal, relatively enormous amounts of fluid may be administered without immediate deleterious effects.

This discussion may be summarised as follows: Fluid therapy has been shown in several cases to be effective in restoring the animal to a state from which it was able to recover further on its own, after large doses of analeptic had proved ineffective (See protocols 1, 5, 8, 9 and 10). In two of these, analeptic convulsions had been reached without signs of respiratory activity. Conversely, in no group where sufficient time has been allowed subsequent to infusion, could it be shown that fluid therapy alone, even within the arbitrary limits imposed in this series of experiments, was not capable of effecting a sustained improvement in the animal's condition. In five of these trials (Nos. 11, 12, 13, 16 and 17), the animals not only

showed signs of permanent recovery, but actually lived in complete health over periods which, although only recorded over a few days, were in actual fact observed over several weeks.

It is interesting to note that, even in those cases when the infusion of physiological saline solution was given very rapidly, no deleterious effect from the imbalance of ions in the blood seems to have been evident as evinced by marked cardiac malfunction or difference in the blood pressure. It is assumed, therefore, that there should be no danger under the conditions of practice where slower infusions are given of any grave disturbance of body functions when saline is used as the diluting agent. Further, there seems to be no case for advising that a crystalloid fluid, Ringer solution, should be used. Ringer solution was used in Nos. 2 and 5, and seemed to give no material advantages over the saline solution used in most of the others.

Therapy with isotonic fluid is recommended therefore as a safe procedure in cases of uncomplicated anæsthetic overdosage under practice conditions. At the same time it is suggested that, where the diagnosis of the animal's general condition and circulatory state is in any doubt, a fluid could be used whose infusion should cause no damage even in hypotension. One such fluid (Dextraven) has been shown to be as efficient as physiological saline solution and Ringer solution in effecting recovery. Administration of such a fluid has the advantage that if the diagnosis of uncomplicated anæsthetic overdosage, or anæsthetic administration associated with hypotension of surgical or traumatic origin, is at all equivocal, the administration of plasma, or a plasma substitute, is indicated in both cases. In cases of anæsthetic circulatory collapse, whereas the treatment by augmentation of the circulatory volume is not sufficient, the administration of a plasma substitute should have no harmful effect; and it may even, through increasing the circulatory volume and possibly the venous return, have a beneficial one.

Summary

(1) A laboratory trial has been carried out in which it was possible to substantiate the results and findings of certain experiences obtained in general practice. (2) An evaluation was made of the respective merits of analeptic and infusion therapy (hæmolavage) for the resuscitation of dogs from long-acting barbiturate anæsthesia. (3) An attempt was made to gauge the safe extent to which analeptics may be employed as an adjuvant to infusion therapy. (4) The extent to which isotonic crystalloid solutions were effective in their powers to resuscitate from anæsthetic overdosage was determined and a plasma substitute (Dextraven) was also tested. (5) The ultimate effects of infusions in the amounts used were evaluated by observations on the behaviour and appetite of a proportion of the subjects during the course of several days after recovery had been effected.

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* Since writing, a narcotic agent has been developed and its antidote may be injected I/V. The antidotal action would appear to occur in the blood stream.

* Goldman (1949) records a case of a war casualty who underwent an operation for the removal of a ruptured kidney. The operation lasted 55 minutes. Although anaesthesia was completely adequate a total of only 0·6 grammes of Pentothal was used.

* Kindly supplied by Benger Laboratories Ltd.

* Cardiozol (Metrazol) Pentamethylenetetrazol kindly provided by Messrs. Knoll A-G., Ludwigshafen (Rhein).

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SOME FACTORS INFLUENCING RESISTANCE TO HISTOMONIASIS IN TURKEYS

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THE pathogenicity of *Histomonas meleagridis* in different species varies considerably. In the domestic fowl it is relatively non-pathogenic. In young turkeys recovery from a clinical infection is rare. Tyzzer (1934) commented that adult turkeys are often found living under conditions which would be expected to lead to heavy mortality in younger stock. Under such circumstances it is possible to premise an age resistance, as has been demonstrated by Desowitz (1951) in chickens. This resistance might take the form either of an actual barrier to invasion by the organism or an increased resistance to clinical disease. Alternatively, resistance might arise as the result of previous infection. Thus, in 1934, Tyzzer described the apparent development under experimental conditions of a resistance to reinfection, following the use of an attenuated strain of *Histomonas*. Tyzzer's work, which has not been repeated, suggested that it was essential to inoculate birds when young and that there was a need for constant reinfection in order to maintain the state of premunition which was apparently the criterion of resistance.

Evidence of the development of an acquired resistance was accepted by some later workers, and Sautter, Pomeroy and Roepke (1950) tested the effect of blood from immunised turkeys in preventing loss from histomoniasis. By contrast, Waletzky (1950) considered that there was no certainty that recovered birds, either with or without the help of drugs, become immune to infection. The develop-

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ment in turkeys of resistance to reinfection and particularly the ability to acquire resistance while being treated is clearly of the highest importance in field control. Swales (1950) suggested that birds treated in the later stages of the disease, or those treated in such a way that disease processes in the cæca were not completely suppressed, were resistant when challenged. Other workers, e.g., Sautter, Pomeroy and Roepke (1950) and De Volt *et al.* (1954) have shown that very little immunity is developed when drugs having a suppressive effect on the parasite are used.

A programme of work in these laboratories includes an investigation into the immunological basis of resistance to histomonas. It is necessary to establish clearly whether or not the age of the bird affects susceptibility to infection.

Age as a Factor in Resistance to Infection

Two experiments were designed to investigate the relationship between age and susceptibility to histomoniasis induced by (*a*) the inoculation of embryonated eggs of *Heterakis gallinæ* or (*b*) the rectal injection of a suspension of *Histomonas meleagridis.*

(a) *Infection through the eggs of Heterakis gallinæ.*

As indicated in Table 1, five groups of birds, varying in age from approximately nine weeks to eighteen months, were infected *per os* each with 1,100 embryonated eggs of *Heterakis gallinæ*, experience at this Laboratory having indicated that a high rate of infection with *Histomonas meleagridis* would follow. The turkeys, which had previously been reared in isolation under conditions which precluded the possibility of accidental infection, were maintained on wire floors until the termination of the experiment twenty days later.

Results.

As indicated in Table 1 deaths from histomoniasis occurred in all groups. In addition, typical lesions of the disease were found in all the survivors when killed on the twentieth day. One bird in Group A (eighteen months old) and one bird in Group C (nineteen weeks old) were moribund when killed. Pathogenicity seemed approximately equal throughout the Groups and the majority of the birds would have died if the experiment had not been terminated.

(b) *Infection by the injection of a suspension of Histomonas meleagridis per rectum.*

Materials and Methods.

Four groups of turkeys, aged seven weeks to twenty months (as indicated in Table 2) were injected *per rectum* each with 5 ml. of a freshly emulsified warm suspension in normal saline, of cæcal tissue from a turkey suffering from advanced histomoniasis. The success of this method of infection, which is similar to that described by Tyzzer (1934) depends to a great extent upon careful attention to details of technique, a high rate of infection being more likely to follow proper preparation of the birds (preliminary evacuation of the rectum) and a repeated inoculation of the warm suspension to ensure that some material actually enters the cæcum. On this occasion, in an effort to reduce the severity of disease and hence to accentuate differences in susceptibility between the groups, only a single

inoculum of infective material was given. As will be seen, the effect of this procedure was to reduce the incidence of infection rather than its intensity. Nevertheless, a considerable rate of mortality was observed.

Results (Table 2).

TABLE 1

Rate of mortality in turkeys infected with *Histomonas* through the embryonated eggs of *Heterakis gallinæ* (experiment terminated on the twentieth day following infection).

Group	Age at time of infection	Deaths from Histomoniasis
A	18 months	$\frac{2}{5}$
B	6 months	$\frac{5}{6}$
C	19 weeks	$\frac{8}{10}$
D	11 weeks	$\frac{6}{8}$
E	9 weeks	$\frac{7}{12}$

TABLE 2

Rate of mortality in turkeys infected with a suspension of *Histomonas meleagridis* (experiment terminated on the twenty-ninth day following infection).

Group	Age at time of infection	Deaths from Histomoniasis
A	20 months	$\frac{2}{3}$
B	7 months	$\frac{12}{18}$
C	9 weeks	$\frac{9}{12}$
D	7 weeks	$\frac{1}{3}$

TABLE 3

Showing the effect of previous infection on the rate of mortality among turkeys infected with the embryonated eggs of *Heterakis gallinæ* (experiment terminated on the twenty-first day following infection).

Group	Age at time of infection	Deaths from Histomoniasis
A	13 months	$\frac{1}{4}$
B	41 days	$\frac{11}{12}$
C	7 days	$\frac{12}{12}$
D	About 13 months (previously infected)	$\frac{0}{5}$

Deaths from histomoniasis occurred in all the groups of turkeys. The survivors were killed on the twenty-ninth day. With the exception of one bird in Group (B) which showed evidence of healed lesions in cæcum and liver, none of the survivors appeared to have been infected.

Post-mortem examination of birds which died during the course of the observation did not indicate any significant differences in the severity of the infection.

The Effect on Resistance of Previous Exposure to Infection

Materials and Methods.

The experiment recorded in Table 1 was repeated using three groups of turkeys aged seven days, forty-one days and thirteen months respectively at the

time of inoculation, but including also a further group of thirteen months old turkeys which, it was believed, might prove resistant to infection. These birds were the survivors of a much larger group which had been exposed to experimental infections during trials of the drug sodium acetarsol. From the observed rate of mortality during these trials it seemed probable that all birds had been exposed to virulent infection.

Results (Table 3).

Following the oral inoculation of embryonated eggs of *Heterakis gallinæ*, there were deaths among the turkeys of Groups A, B and C, but none in the previously infected Group D. The experiment was terminated on the twenty-first day following infection. Post-mortem examination of the surviving birds in Groups A and B showed that lesions had developed in the livers and cæca. By contrast none of the birds in Group D showed evidence of disease, although young *Heterakis* worms were recovered from the cæca of three out of the five. This indicated that the usual conditions for successful infection with *Histomonas* had obtained.

After carefully washing the contents of the cæca of the turkeys in Group D in order to isolate *Heterakis* worms, the cæca were emulsified in warm normal saline and injected *per rectum* into six susceptible young poults. Thirteen days later these poults were killed and examined for evidence of histomoniasis. Four of the poults did not show any evidence of disease, but livers and cæca in the other two showed lesions. This indicated that the turkeys in Group D, although resistant to the clinical effects of disease, could nevertheless harbour the organism.

Conclusions and Discussion

The data recorded in Tables 1, 2 and 3 indicate that there is no significant difference in susceptibility referable to age whether challenge is by the rectal inoculation of a suspension of histomonads or the ingestion of the embryonated eggs of *Heterakis gallinæ*. The number of carefully isolated birds which could be retained for this type of observation was inevitably small so that an accurate analysis of the degree of morbidity in the various Groups is not possible. In general, however, it did not appear that young birds (up to three months old) died in a shorter time after infection than did older birds. In many instances, however, liver lesions seen in these young birds were not the typical yellow concentric rings with a necrotic core seen in older birds, but more diffuse grey-white areas of necrosis. These bore a close resemblance to the lesions of experimental histomoniasis in young chickens.

By contrast, resistance shown by previously infected birds was most marked thus confirming the view of previous workers that an acquired resistance can arise. It is clear also that resistant birds may harbour a latent infection. In the observation recorded in Table 3 it is, of course, not certain whether the particular organisms demonstrated in the resistant Group D, originated from the initial or the challenge infection. Other observations, not reported here, have, however, shown that turkeys may harbour infection for several months without showing clinical evidence of disease.

It is apparent that under field conditions a percentage of young poults must acquire an infection which is relatively non-pathogenic, but which leads to a state

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of resistance. The acquisition of low-grade infection might result from the existence of avirulent field strains or alternatively from an initial invasion by a very few organisms.

The existence of avirulent field strains of *Histomonas* was surmised by Tyzzer (1934), but has never been confirmed. The alternative hypothesis, i.e., that low-grade infection may result from initial invasion by a few organisms, also does not seem clearly to have been demonstrated, although Lund (1955) produced some evidence to suggest that a less virulent infection might result from a rectal inoculation with small numbers of organisms. Such a conclusion is not in conformity with our usual experience here where, particularly as a result of the " natural " infection resulting from the ingestion of the eggs of *Heterakis* an " all or nothing " effect is usually observed. Turkeys either contract clinical infection which usually results in death or else show no signs of disease, give no indication of infection on post-mortem examination, and remain susceptible to reinfection.

Under experimental conditions it seems necessary to give at least 1,000 embryonated eggs to each poult in order to set up disease. If a smaller number of eggs is given many poults apparently escape infection. This observation has been assumed to indicate that the rate of infection of the eggs of *Heterakis* is low under field conditions, but that the invasive capacity of those organisms which do occur in the eggs is uniformly high.

Further immunological studies in this field would be helped by the development of techniques for setting up in predictable fashion a patent but non-lethal infection with *Histomonas meleagridis* in young poults.

Summary

(1) Under experimental conditions turkeys of different ages appeared to be uniformly susceptible to histomoniasis resulting either from feeding embryonated eggs of *Heterakis gallinæ* or from the rectal inoculation of histomonads.

(2) The development of resistance to reinfection with *Histomonas meleagridis* is confirmed.

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NEWS FROM BORNEO

A COMMONWEALTH co-operative effort in North Borneo is safeguarding all types of livestock against the inroads of disease and placing valuable veterinary knowledge in the hands of Asians.

Headquarters in North Borneo are at Kepayan, near Jesselton, the capital. E. H. Holland, M.R.C.V.S., is Veterinary Officer in charge of the Animal Husbandry Section of the North Borneo Agricultural Department.

On the technical side is an Australian, B. Leyland. His job is to perform the laboratory work and to train North Borneo personnel.

Ceylon is represented by S. Krishnanandan, who is working at the Kepayan Laboratory.

This Commonwealth team—and their North Borneo colleagues—can claim one major success among many other achievements.

In 1951, when Holland first arrived in North Borneo, Surra (Trypanosomiasis) was rife throughout the colony's pony population. Over 700 horses a year have been known to succumb to this blood-parasite infection.

Today, Surra is under control in North Borneo. The last new case was in 1953. Subsequently one case of relapse occurred, but the final case was in November, 1954.

Behind the fight against this lethal disease, which affects horses throughout Asia and in parts of Africa, is a fine record of field work and research by the Animal Husbandry Section.

At first, drugs were used in the treatment of the disease. When these were employed, it was possible to control and, finally, to stop an outbreak. But when veterinary officers left the district after providing treatment, the disease broke out again.

A register of ponies in various districts, including those which had been affected by Surra, was made. Routine monthly treatment with drugs was given to these ponies and the incidence of the disease dropped rapidly.

It was proved that by keeping old cases permanently under treatment, the spread of the disease could be stopped. All the ponies recorded as old cases were purchased and destroyed—Surra vanished. So did the old North Borneo farmers' belief that buffaloes and cattle always spread Surra to horses.

Since the last case was recorded, buffaloes or cattle have not re-infected any horses. It has been proved that the actual reservoir is the horse.

Another success has been registered in the fight against Ranikhet, better known as Newcastle Disease, in poultry.

A vaccine was used throughout the colony and this reduced poultry mortality rates by about 90 per cent. Ranikhet has been controlled, and a former 90 per cent death rate has been changed to a 90 per cent survival figure.

The main work of the laboratory is investigation. The idea is the production of effective vaccines. The latter are administered by the livestock handlers throughout North Borneo's 29,388 square miles. This method has proved to be a much more effective way of fighting animal diseases than by relying on an expert to cover on his own vast—and often inaccessible—areas of the colony.

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Two North Borneo trainees are at work in the laboratory. The knowledge acquired in the laboratory at Kepayan is applied by officers in the field. Locally trained men have been taught how to collect the material and specimens needed for investigation.

Commonwealth co-operation is playing a major part in bringing the technical skills of the more advanced nations into North Borneo.

REVIEWS

VETERINARY GUIDE FOR FARMERS, by G. W. Stamm. Windsor Press. U.S.A. Price 27s. 6d. (approx.).

LOOKING at the table of contents one realises that this text-book of 370 pages, now in its third edition, covers a great number of subjects concerning various diseases affecting cattle, horses, pigs, sheep, dogs and poultry.

No one particular disease or surgical operation is dealt with in great detail, while some of the diseases and deficiencies of economic importance are dismissed with considerable brevity. For instance, "Nutritional diseases of poultry", which are discussed in two pages, surely warrant more space. These disorders, brought about by the lack of vitamin or mineral in the diet, are of primary importance to the poultryman, especially when the flock is young and growing fast.

The book is of less use to the British farmer than to his American counterpart, because the latter is able to obtain at the local drug store almost all the drugs and vaccines he requires to treat his farm livestock. This is not so in Great Britain.

There are many good and useful photographs and line drawings which illustrate the text.

This book is written for farmers and is probably rather elementary for the veterinary surgeon or student.

THE ROWETT RESEARCH INSTITUTE. Collected Papers. Summary and Subject Reviews. Volume XIII. Reid Library. 1957.

THE 86 collected papers which are listed in this publication form a summary of the work carried out during the academic year 1955-56. These papers are themselves summarised in a preface by the Director of the Rowett Institute, Dr. D. P. Cuthbertson, giving a clear picture of the continuing research which varies from the fundamental to the applied aspects of Animal Nutrition. Additionally, there are two reviews which describe in more detail particular lines of research. The first by Dr. R. L. M. Synge is concerned with the breakdown of protein in the rumen and its significance in the nutrition of ruminants; the second, by Mr. J. A. Crichton and his colleagues, deals with the topical subject of hexœstrol in beef and mutton production.

MICROBIAL ECOLOGY. 7th Symposium of the Society for General Microbiology. Edit. by R. E. O. Williams and C. C. Spicer. Cambridge Univ. Press. 1957. Pp. 388. 32s. 6d.

IN April, 1957, the Society for General Microbiology met and discussed Microbial Ecology. The 17 papers prepared by invited contributors were avail-

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able before the meeting. This volume contains the results of this attempt to summarise current knowledge and views on this aspect of Microbiology. An introductory paper by C. J. Shepherd deals with the genetic basis of microbial variation and this is followed by contributions from: Jane Gibson, L. F. Hewitt, R. F. Stanier and Germaine Cohen-Bazire, M. Ingram and F. H. Johnson. These five papers form a group which considers the interaction of microbes with their inanimate environment and this includes the effect upon microbes of variations in p^H and Eh, the role of light in the microbial world and the part played by high concentrations of sugars and salts and the action of pressure and temperature. The next three papers are by P. W. Brian, E. S. Anderson and C. L. Duddington and form another group in which consideration is given to the interactions between microbes themselves; there is clearly some ecological significance in antibiotic production, in bacteriophage activity and in the attacks of predacious fungi. This first half of the Symposium is therefore an account of our knowledge, and of the views of authors, on these influences which effect the distribution of microbes.

The latter part of the book begins by discussing the survival of fungi and of some of the factors in the life of free-living protozoa; the chapters are by Lilian Hawker and by J. A. Kitching and these two papers are followed by an account of a study made by H. T. Tribe on the development of soil micro-organisms on buried cellulose film. The role of plant hosts in microbiology is discussed by F. C. Bawden and the influence of man and animals on the ecology of microbial agents is dealt with by R. Lovell. C. H. Andrewes deals with the ecology of viruses and G. S. Wilson with selection and virulence in bacteria. The final article is by K. M. Smith who discusses factors which influence the spread of plant viruses by arthropods.

Doubts may be expressed as to whether there is sufficient information available to warrant a symposium on microbial ecology. A perusal of this volume should give a satisfactory answer because here one finds a valuable basis for further studies. The contributions cover many aspects and they present problems and focus attention on the need for more experiments and for further observations: many fields are open for investigation and the selective influences which are at work in microbial ecology are as numerous as the views and ideas expressed.

A HANDBOOK OF ANIMAL PHYSIOLOGY, by E. M. Pantelouris, B.Sc., Ph.D. London: Baillière, Tindall & Cox, Ltd. Pp. xx + 248 with 58 illustrations. 25s. net.

THIS book is designed to be read by veterinary, agricultural and biological students before attempting more detailed and specialised study of the subject. The author has succeeded in admirably condensing the salient features whilst maintaining a good balance throughout, particularly between the mammalian and general aspects of the subject. Conflicting viewpoints and unsolved problems have not been ignored. The result is interesting, readable and quite valuable.

CORRESPONDENCE

To the Editors,

GENTLEMEN,

We wish to apologise to Dr. Hutt for the error which occurred in our paper on encephalomalacia which appeared in the BRITISH VETERINARY JOURNAL in April, 1956. The reference to his work was taken from "Annotated Bibliography of Vitamin E in Chicken Nutrition, 1929 to 1954", published by Distillation Products Industries, New York. The abstract of the article by Howes and Hutt appearing in this Bibliography is obviously inaccurate. It is our usual practice to refer to the original article when quoting other authors' work; but in this case, for reasons which we cannot recall, we must have omitted to do so.

Yours faithfully,
R. B. A. CARNAGHAN.
L. M. MARKSON.

The Editors,
THE BRITISH VETERINARY JOURNAL,
7 and 8 Henrietta Street,
London, W.C.2.

Hutt, F. B. (1957): *Brit. vet. J., 113,* 399.
Carnaghan, R. B. A. and Markson, L. M. (1956): *Brit. vet. J., 112,* 140.
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NEWS

DR. W. P. BLOUNT, the senior member of the Company's agricultural staff, has been appointed a Director of the British Oil & Cake Mills, Ltd. This appointment to high office in one of the great animal food producing firms is a great honour to Dr. Blount, but it is also a sign that the value of veterinary service to an industrial organisation has been recognised. Dr. Blount has attained a high reputation as an authority on nutrition as applied to farm animals and particularly with regard to poultry. He has the facility of being able to apply the lessons learnt in the laboratory and by biological experiment in the field to the benefit of agriculture so that the ordinary farmer and the public may profit.

An able speaker, writer and lucid broadcaster, he has done much to advance animal husbandry in this and other countries. We wish him well in his new sphere and venture the thought that by this appointment an example has been set which could be followed with advantage by other organisations.

OBITUARY

Professor G. H. Wooldridge

As we are going to press we learn, and with great sorrow, of the death of Professor Wooldridge. He was joint editor of the VETERINARY JOURNAL from 1906-1914.

He has been teacher, friend and adviser to so many generations of students

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and practitioners that he became almost a beloved institution. We hope to publish an account of his life and work at a later date, but in the meantime we take this opportunity of extending to Mrs. Wooldridge, his gracious helpmate in all his endeavours, our deepest sympathy in her own sad loss.

ANNOUNCEMENT

MESSRS. ALLEN & HANBURYS, LTD., announce a new improved presentation of Veterinary Alficetyn Aerosol. Veterinary Alficetyn Aerosol is for the treatment of Contagius Foot Rot in sheep. Each Aerosol container holds 50 c.c. of Veterinary Alficetyn Paint (equivalent to 5.0 g of Chloramphenicol B.P.) together with a suitable propellent. Veterinary Alficetyn Paint contains 10 per cent w/v of Chloramphenicol B.P. and 0.5 per cent w/v of Crystal Violet in Industrial Methylated Spirit.

ERRATA

Owing to a mistake the following illustrations were omitted from the article by Markson and Carnaghan in the August, 1957 issue, for which we apologise.

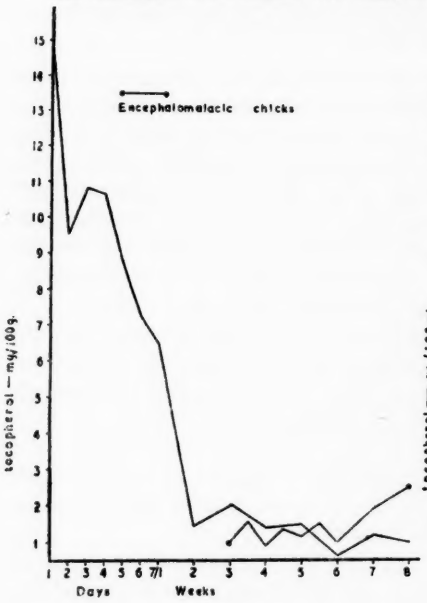

FIGURE 1

Liver tocopherol levels of normal and affected chicks.

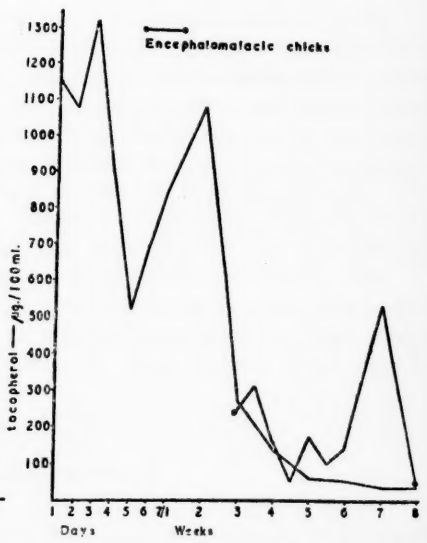

FIGURE 2

Plasma tocopherol levels of normal and affected chicks.